CMHC
Canada Mortgage
and Housing Corporation

SCHL
Société canadienne
d'hypothèques et de logement

A STRAW BALES/
MORTAR HOUSE
DEMONSTRATION PROJECT

Prepared for:

Project Implementation Division

Policy Research and Programs Sector

Canada Mortgage and Housing Corporation

by:

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Canada Mortgage and Husing Corporation, the Federal Government's housing agency, is responsible for administering the National Housing Act.

This legislation is designed to aid in the improvement of housing and living conditions in Canada. As a result, the Corporation has interests in all aspects of housing and urban growth and development.

Under Part V of this Act, the Government of Canada provides funds to CMHC to conduct research into the social, economic and technical aspects of housing and related fields, and to undertake the publishing and distribution of the results of this research. CMHC therefore has a statutory responsiblity to make widely available, information which may be useful in the improvement of housing and living conditions.

This publication is one of the many items of information published by CMHC with the assitance of federal funds.

DISCLAIMER

This study was conducted by Louis Gagné for Canada Mortgage and Housing Corporation under Part V of the National Housing Act. The analysis, interpretations and recommendations are those of the consultant and do not necessarily reflect the views of Canada Mortgage and Housing Corporation or those divisions of the Corporation that assisted in the study and its publication.

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A. INTRODUCTION

This report describes the construction of two houses using the straw-bale/mortar external wall system. This method of wall construction was first used in the building of my own house and promoted for its advantages, namely: low construction materials, simple building techniques, exceptional fire retardation properties, sound structural qualities, and a high insulation value.

In 1982, C.M.H.C. Housing Technology Incentives program provided funding to demonstrate the practical applications of the straw-bale/mortar system as a load-bearing wall in residential construction. This demonstration project included the erection of a sample wall and the testing of its performance by independent consultants in accordance with recognized procedures for thermal resistance, load bearing, moisture penetration and fire endurance tests. The results indicated that the sample wall met or exceeded residential construction requirements in the areas tested.

The advantages of this method of wall construction are particularly relevant to northern and natives communities. The potential of its use was investigated in a report entitled "A Feasibility Study of An Alternative Building Method in Native Communities." This study was carried out with the assistance of a C.M.H.C. External Research Program grant.

The construction of the two houses described in this report has been financed and carried out by private individuals interested in utilizing the straw-bale/mortar technique in the building of their houses. My involvement in the construction of these houses and the preparation of this report was assisted by funding from the Project Implementation Division, C.M.H.C.

The objectives of this report are to document and describe the techniques and details of the building method, as well as the construction process and the related construction and labor costs, so as to allow others to assess its appropriateness of use. Long-term monitoring and field testing of the technical performance of these houses will be carried out.

As this method is developmental in nature, each new construction leads to new refinements in the tools and building details. This report also illustrates these improvements to date.

B. THE STRAW-BALE/MORTAR WALL CONSTRUCTION METHOD

1. Straw as a Building Material

In Canada, straw is not used currently for building purposes, but in Europe and also in most parts of the world it has been employed for thousands of years and still is. In Asia, Africa, and South America, straw is mixed with clay to make bricks and adobe walls.

Very expensive and elegant roofs are still made out of straw in most European countries. They generally have a steep pitch, and the straw is tightly set in place with a sledge-hammer. When they are well made, these roofs will last more than a hundred years. (see figure)

2. Method

a) Objective

This technique is intended to build a concrete structure around the straw bales. To do so, special forms are used in combination with the straw bales to shape vertical and horizontal concrete joints. The thick consistency of the concrete and added straw mixture provides binding before the mortar has set, which allows for the immediate removal of the forms. It is also the same factors plus the firmness of the bales that permits me to build an eight foot wall in a day. But first it must be understood, and this is a very important point, that the bales stabilize the structure while the concrete is curing, but once it has set, all the bales can be pulled out without affecting the structure. (see figure)

When the walls are up, the function of the bales is to insulate the walls and to serve as a supporting surface for the plaster work.

b) Mortars

Structure: the structure is essentially made of concrete, which is a mix of heavy gravel with only a small proportion of lime as compared to cement. Straw is added to ensure proper binding while the mortar is curing.

The mixture is made of four parts of cement and one part of lime, combined in a ratio of 3 to 1 with coarse gravel. A low content of water is necessary to keep the mixture thick. Straw is added until saturation; if too much straw is mixed it will bunch up; if there is not enough, the joints tend to break on the sides when the forms are taken off.

The balance of water and straw is most important and proper guidance is required to keep it right.

Plaster: the parging mortar is made with fine screened sand and mixed with equal proportions of lime and cement in a ratio of 3 to 1. The mixture needs a soft texture to spread smoothly on the walls.

Whitewash paint: this paint is composed of three parts lime for one part white cement, and it has to be kept in an almost liquid state. The walls have to be wet before the application of the paint.

c) Straw Bales

Soft and crooked bales were utilized on the houses I built, but they slowed down the work considerably. With soft bales a lot more concrete than needed will be rammed into the structure as the bales tend to contract when the mortar is compacted between them.

Crooked bales will necessitate more parging to get the surfaces even. If possible, it is recommended to choose good, tight and straight bales to speed up work.

Finally, the straw bales have to be dismantled to fit in corners or against windows. The section taken apart from the bale to provide the right length in those corners does not need to be secured with string, since the mortar structure rammed in place will hold it together.

d) Tools and Crew

The following tools are needed: shovels, a small cement mixer, a wheel barrow, and the special forms for the mortar joints.

Corner forms made of two member (500 mm/244 mm) fastened together at a 90° angle are properly set to level and braced in place on the four corners. A string is stretched between the corner forms to provide proper guidance. Besides guiding the erection of the building, the purpose of those forms is to mould a structural concrete corner post as the walls go up.

The ideal crew to work on those walls is composed of three men, one mixing the mortar, one taking care of the wheelbarrow and shoveling the mortar into forms which are handled by the third man who builds up the walls.

3. Properties

a) Structure

The load bearing capacity of the walls comes mainly from the concrete structure but also from the mortar applied on the surfaces. As is shown in figure , all the bales can be pulled out of their concrete compartment without affecting the structure. The bales and the twine holding them have no effect in the load bearing capacity of the walls. (see table 1 and figure 2)

b) Fire Resistance

The straw bales/mortar structure wall has proven to be exceptionnally resistant to fire. The complementarity in the nature of the materials allows those performance.

The straw bales hold enough air to provide good insulation value but because they are compacted firmly they don't hold enough air to permit combustion.

Each straw bale is isolated in its own mortar (concrete) compartment so fire cannot spread in the walls.

Finally, the volume of the walls enables them to absorb large amounts of heat.

Figure shows the specimen which served for the small scale fire test done at N.R.C. Fire Research section, and Table 1 taken from their report shows the results of the test.

c) Insulating Characteristics

The straw bale by itself has an insulating factor of R50, but in association with the concrete structure the insulating capacity of the walls is R36.

Here again, the complementarity of these two materials, so different in nature, serves its purpose. The result of combining the insulating qualities of the straw bales with the density of the mortar structure, is a thermal mass which retains heat. The good insulation value of the straw bale minimizes heat loss, and the massive structure absorbs large amounts of heat and releases it constantly. It's my third winter in my straw bale/mortar (concrete) house, and I have witnessed this phenomenon many times.

My house is heated with an ordinary wood stove which burns wood rapidly. Also, I have the large windows of my house which are not air tight and allow a fast air exchange cycle. In the morning, when I get up, the fire will be out for a five hour period, and in cold, windy days of winter, the temperature inside the house will be around 16°C. Even if the air is cold inside, I don't react to it because the walls have gathered heat and it feels warm.

The opposite situation is also verified; when I leave for two or three days, I only have a 1,200 watt base board to heat the entire house, and when it's really cold the temperature inside the house will remain around 16°C. After these days, the walls will have lost the absorbed heat, and it will come to level with the inside air. When I come back, I'm able to heat up the air rapidly with my wood stove to 28°C. Even then it feels cold because the walls are still at 16°C, and it will take two days before we get the warmth back in the house.

That type of wall performs like a flywheel; once it absorbs energy it will keep it, but once it loses it, it will have to be heated for a while before it regains it.

d) Humidity

The humidity test was done at my house three years ago, showing an average of 13% relative humidity. This is a dry state for a wall since the humidity inside a house is around 35%.

Last winter C.M.H.C. tested the walls for humidity. They installed test wires inside the north-west wall and the east wall, including readings in the bathroom. Of the nine test locations only two recorded any humidity. Both were on the bottom row at the footing. One showed 11%, the other 8% relative humidity.

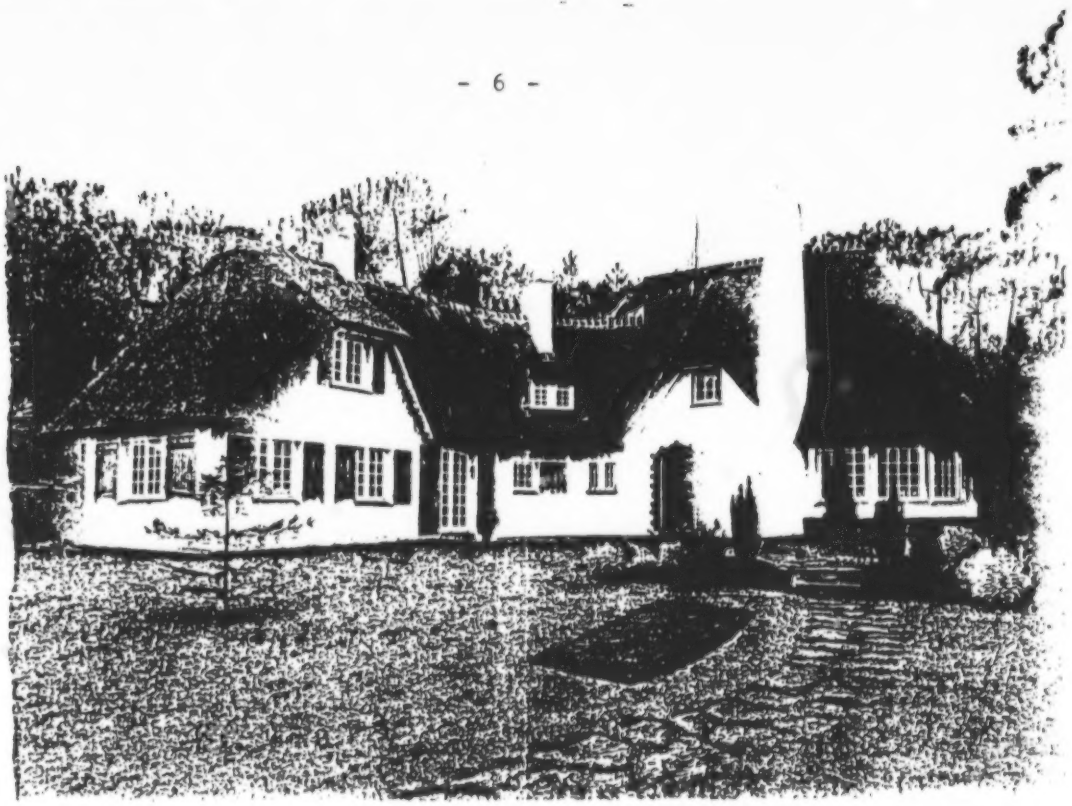
These humidity tests, taken at three year intervals, demonstrate clearly the tendency of the walls to dry out and remain dry.

RECOMMENDATIONS

To avoid any problems with humidity in the walls, certain precautions should be taken. These recommendations were deduced from problems encountered while building the houses. Those problems will be exposed further in the report.

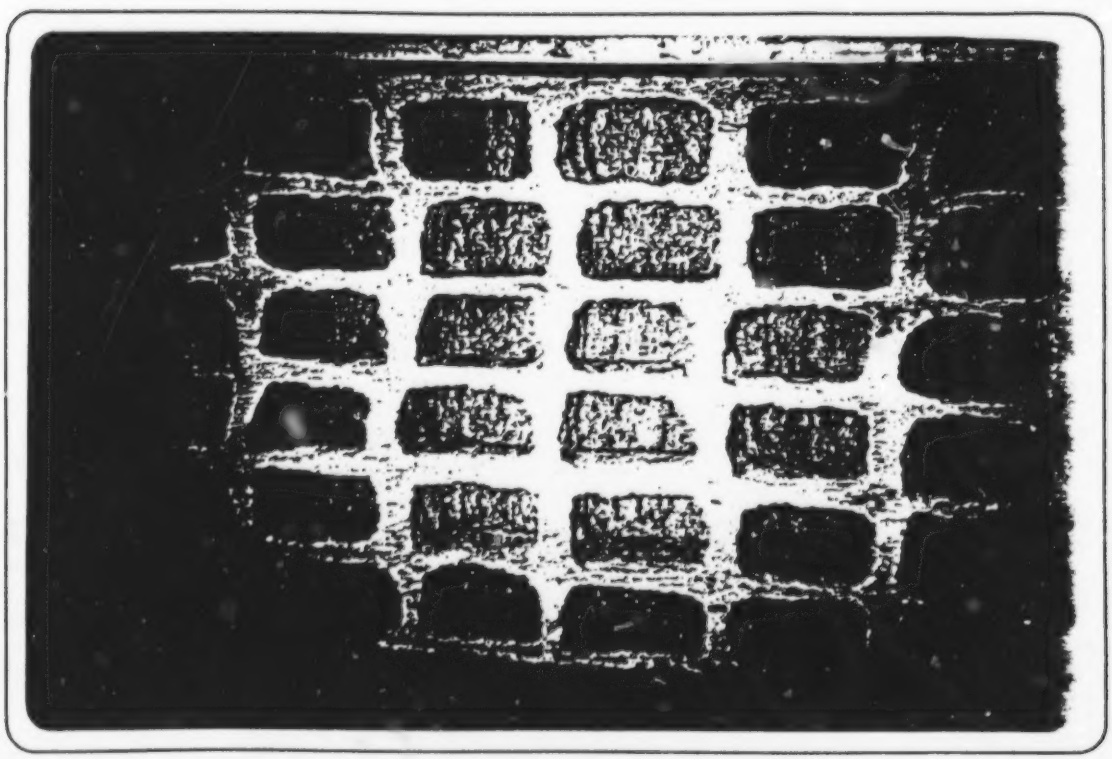
1) If the basement is made out of straw bales/mortar, it's important to make sure that the underground bales are completely dry since they remain the the same state once the walls are closed with parging.

2) It's better to have the roof on before applying the mortar coats on the wall surfaces, because the bales can get wet if they are not properly protected from rain, and the capability of the walls to dry out is considerably reduced when the surfaces are plastered.



B.1

This elegant house in Normandie, France, has a straw roof, and as can be seen the pitch is steeped and the straw densily packed.



B. 2

The bales were taken out from the structure of this experimental wall.

Here the massive concrete structure of the wall is clearly shown and its irregularity due to the shape of the bales doesn't give anything away to the overall solidity of the wall.

Scanada

TABLE 1

READING	LOAD				DEFLECTION	
	COMPRESSIVE		TRANSVERSE		VERTICAL mm	HORIZONTAL mm
	No. of Cinder blocks	Equivalent load (kN)	No. of Cinder blocks	Equivalent load (kN)		
1	82	14.48	3	.53	0	0
2	164	28.96	6	1.06	0	0
3	246	43.44	9	1.59	0	0
4	328	57.92	14	2.12	0	0
5	428	79.11	18	3.19	0	0
after load removed	0	0	0	0	0	0

Fig. 3 Loading platform fully loaded.

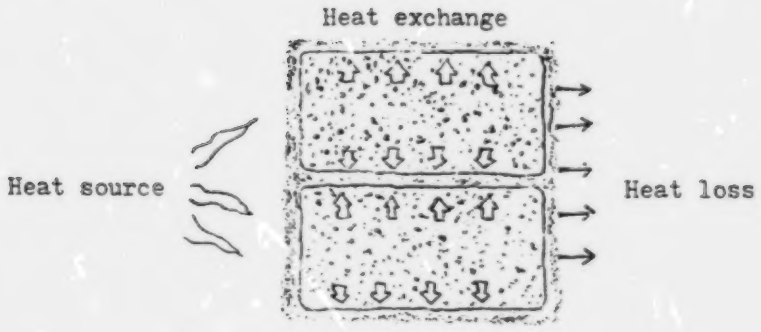


Diagram - The mortar joints, because of their low heat resistance, allow thermal exchange and absorption between the bales.

During the fire test, the thermocouples placed on the sample wall section indicated minor differences in the heat flow through the straw and through the mortar joint. This is indicative of a uniform heat distribution inside the wall.

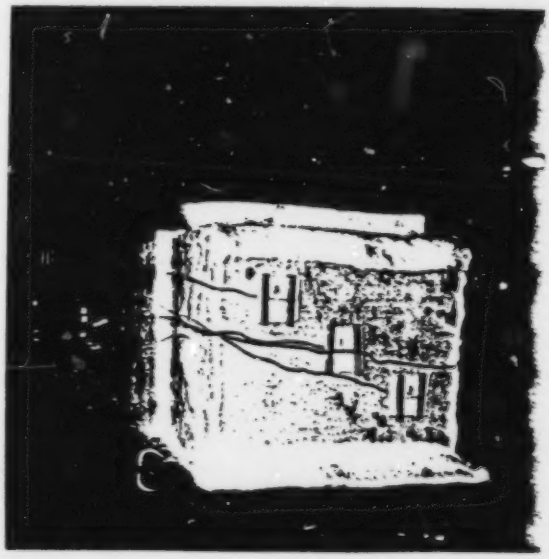


Fig. B.4 Sample wall used in fire testing, shown here with thermocouples.

TABLE II

Time (min)	Furnace Temperature (°C) Average	Prescribed	Specimen Temperature (°C) Unexposed Side TC 1	TC 2	TC 3	Avg.
0	20.2	20.0	24.6	24.1	23.7	24.1
5	433.8	538.0	24.6	24.2	23.8	24.2
10	672.5	704.0	24.7	24.2	24.0	24.3
15	738.0	759.0	24.7	24.2	23.7	24.2
20	786.1	794.0	24.6	24.2	23.6	24.1
25	804.9	821.0	24.6	24.1	23.5	24.1
30	831.0	843.0	24.5	24.0	23.5	24.0
35	858.8	862.0	24.3	23.8	23.3	23.8
40	863.1	878.0	24.2	23.7	23.2	23.7
45	892.4	892.0	24.3	23.8	23.3	23.8
50	894.2	905.0	24.2	23.8	23.2	23.8
55	911.8	916.0	24.2	23.8	23.2	23.8
60	917.5	927.0	24.3	24.1	23.3	23.9
65	931.6	937.0	24.5	24.5	23.6	24.2
70	935.3	946.0	24.6	24.8	23.7	24.4
75	947.0	954.0	25.0	25.6	24.3	25.0
80	957.7	963.0	25.5	27.1	24.9	25.8
85	966.1	971.0	26.2	29.1	25.9	27.1
90	973.3	978.0	27.3	31.7	28.8	29.3
95	981.0	984.0	29.0	35.1	33.7	32.6
100	987.6	991.0	30.7	38.5	39.4	36.2
105	994.7	997.0	32.1	42.1	44.6	39.6
110	1000.5	1002.0	33.7	45.6	49.2	42.8
115	1005.8	1006.0	35.1	48.7	52.8	45.5
120	1010.0	1010.0	36.5	51.6	55.8	48.0
130	1017.7	1017.0	39.1	56.5	55.8	48.0
140	1025.7	1024.0	41.5	60.1	62.2	54.6
150	1034.3	1031.0	43.7	62.6	63.7	56.7
160	1042.7	1038.0	45.7	64.3	64.5	58.2
170	1057.5	1044.0	47.8	66.1	65.3	59.7
180	1056.7	1046.0	49.9	66.8	65.3	60.7
190	1068.0	1059.0	51.7	67.2	65.3	61.4
200	1075.1	1066.0	53.3	67.5	65.2	62.0
210	1080.1	1072.0	55.0	67.7	65.0	62.6
220	1086.3	1079.0	56.6	67.7	64.7	63.0
230	1096.0	1087.0	58.1	67.6	64.5	63.4
240	1102.8	1093.0	59.2	67.5	64.0	63.6

C. THE HOUSE IN CHELSEA

1. Characteristics

This house is 13,208 mm long and 9,550 mm wide. The basement and the main storey are made out of straw bales/mortar, the second storey is built in the high pitch roof.

The floor space for the basement and the main storey is 111.67m^2 (1,202 ft^2), the second storey has a surface of 69.64 m^2 (750 ft^2), and the total floor area is 292.98 m^2 (3,154 ft^2).

The interesting aspect of the house are the basement walls which were done with straw bales and mortar. The outside surface of the basement wall was protected with three coats of mortar and a coat of tar. A good drainage system was also installed around the footing.

2. Structure

The project started in October 1984, and when it stopped in mid-November the basement with the first floor, was in place. The inside wasn't parged and the outside was covered to about two feet above ground level. The tar was applied up to ground level. The remaining bales were stored inside the basement close to the walls. Finally the four windows were closed in.

During the winter everything went well and the owner was surprised to find out that the temperature inside the basement always stayed above the freezing point. Even in the coldest days of winter, when he went inside he had to take off his hat and coat because the insulating value of the walls and the snow on tope of the floor kept the heat coming from the ground.

This gives a good clue on the amount of energy that could be saved with basement walls made out of straw bales and mortar.

There is an interesting point to be made about the structure. The basement was done in clay soil, where ground movements are most hazardous and despite the fact that it wasn't heated during the winter, nothing moved or cracked.

3. Humidity

Despite my recommendations to overhang the plywood across the walls and to use tar paper with glued joints to seal the floor for winter, the owner insisted on using plastic folded around the walls and above the floor. He also stopped the plywood an inch before the inside surface of the walls. He relied on the plastic to keep the water out of the basement and off the walls.

In spring we observed that the plastic wasn't sufficient to keep the water out of the basement. Water dripped everywhere inside but

mainly it came in between the edge of the floor and the inside surface of the wall. The water was trapped between the bales in the wall and the bales stacked against it.

Like any other insulating material, straw bales have a lot of air spaces that soak up water, and we had to pull out about seventy bales that got wet in the walls.

What we observed when we pulled out those bales, is that the outside surface of the wall and the straw in contact with it were dry. it showed that the water didn't go through the walls from the outside. The sections of the walls where no bales were stacked remained dry.

It's obvious that the problem occurred because the floor was not properly sealed and also because the bales stacked against the walls trapped the water.

4. Materials cost and labour involved

It's most difficult to obtain precise information on the total material cost for this house, mainly because the project stopped for eight months. Material cost is available only for the main storey.

a) Cost breakdown for materials

Item	Amount	Unit Cost	Total Cost
Straw bales	300	$ 1.50	$450.00
Cement and lime bags	140	$ 6.00	$840.00
Sand and crushed stones loads	2	$140.00	$280.00
Total material cost			$1,570.00

b) Labour involved

It took four days with a three men crew to build the walls with the plate on top ready to receive the roof.

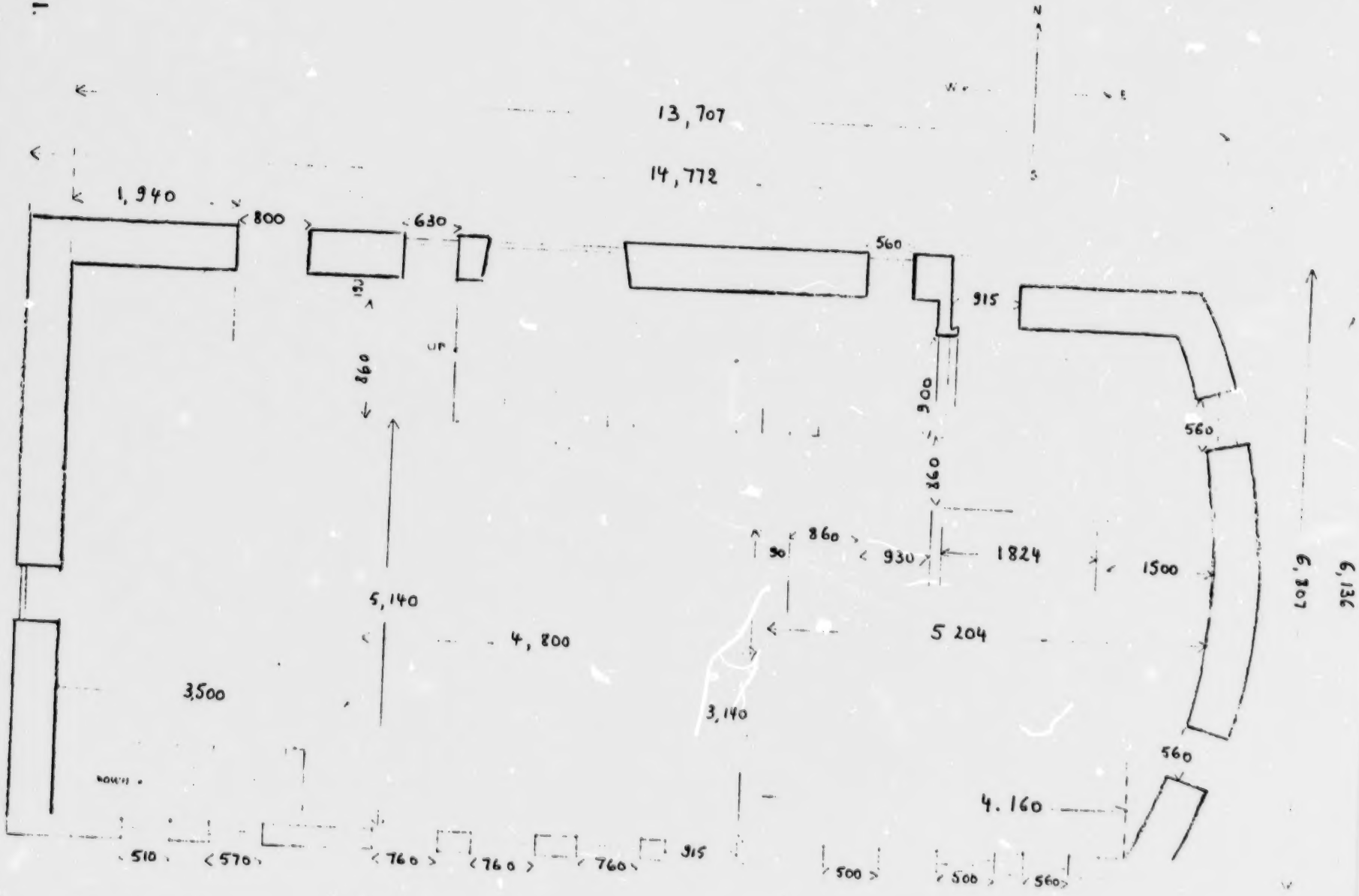
Plastering the inside walls took three days to a two men crew. the outside walls took four days because we were starting from ground level so we had more surface to do.

Altogether, seven days of work done by a two men crew were necessary to apply two coats of mortar on the inside and outside surfaces of the walls.

Usually, after the second coat of mortar a whitewash paint made of lime and white cement is applied on the walls, but in this case the owner prefers a third coat of white stucco.

5. Floor Plans and Wall Details

C.1.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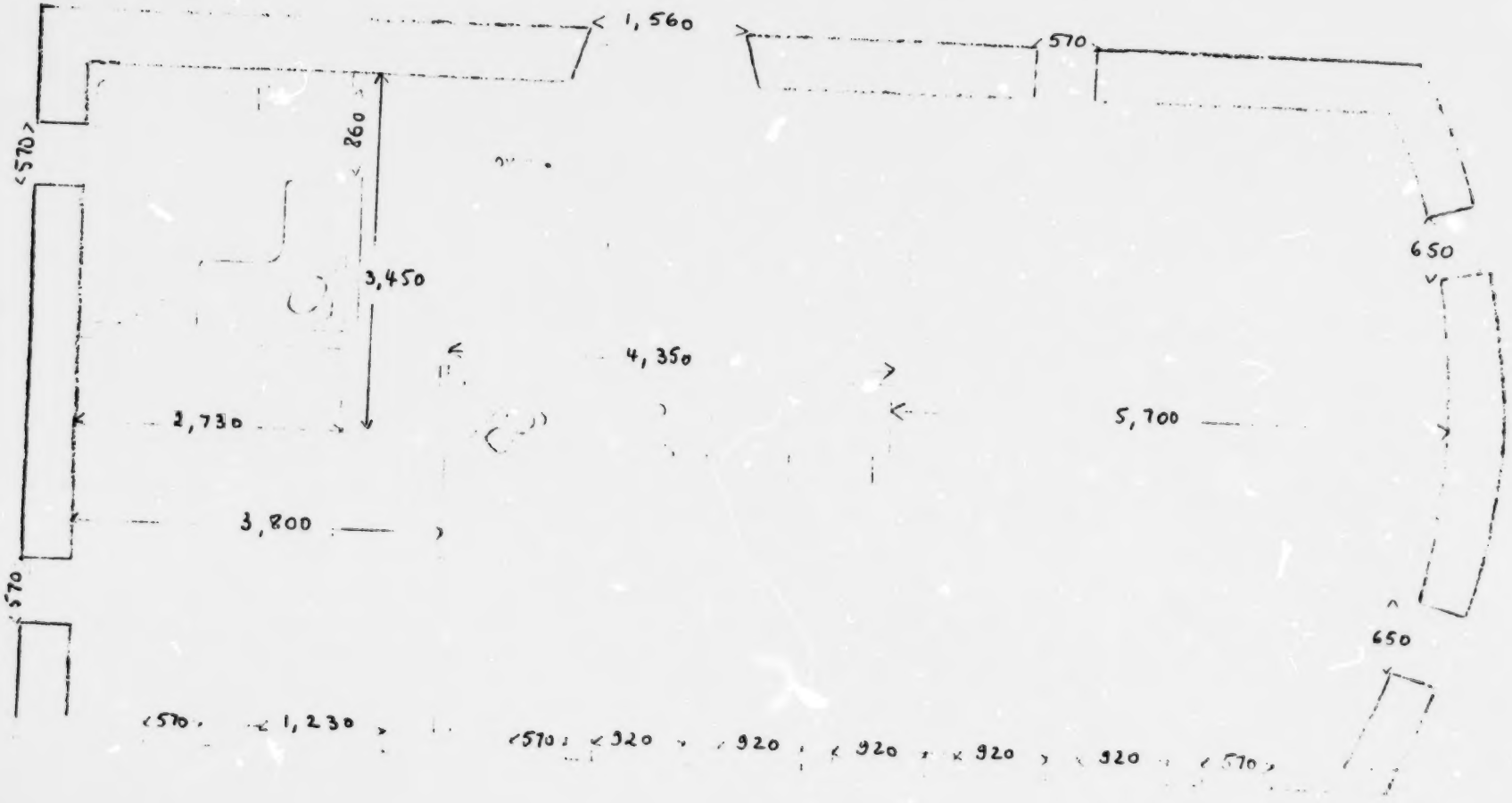
Scale = 1/60

C.2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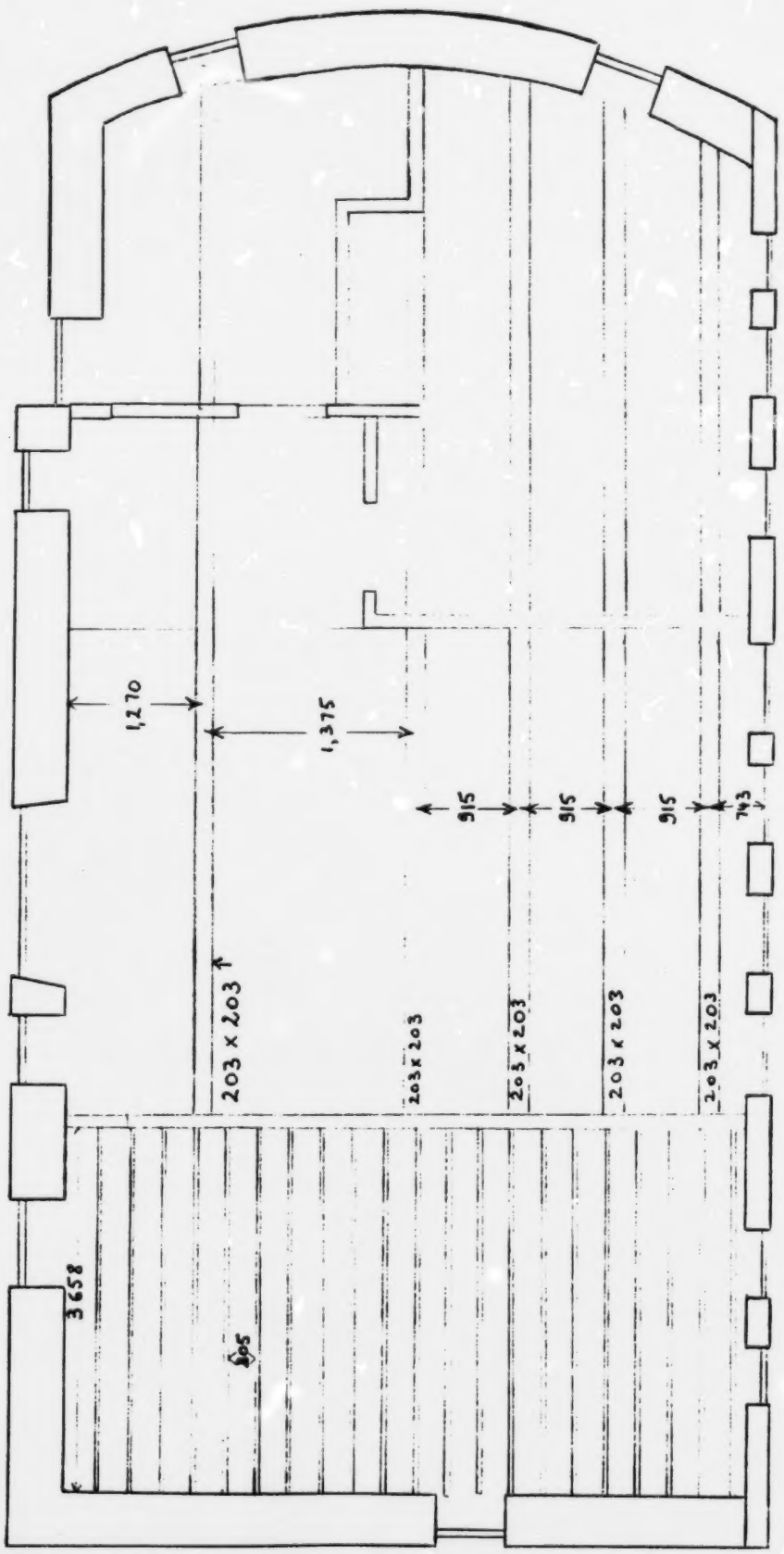
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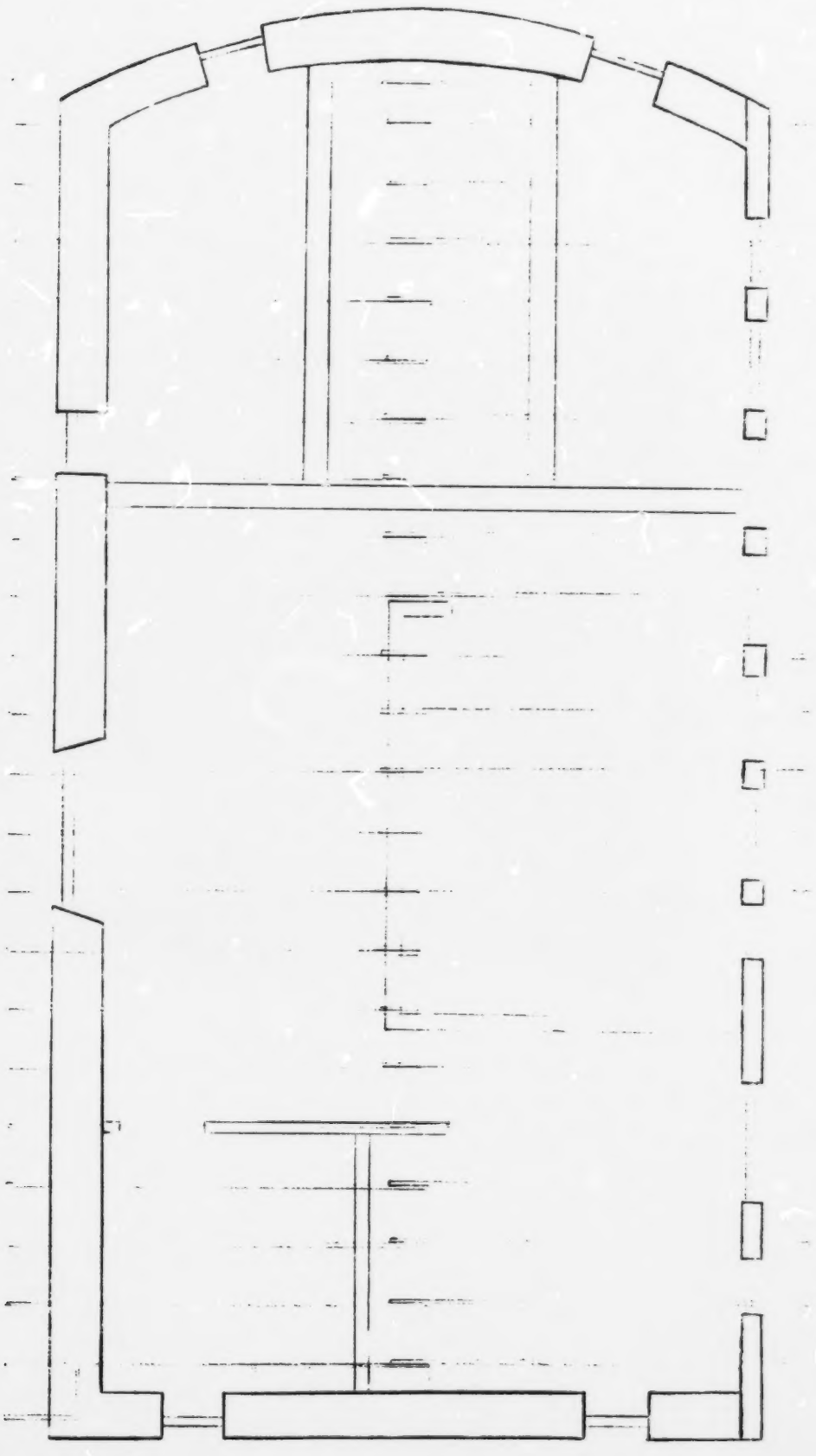
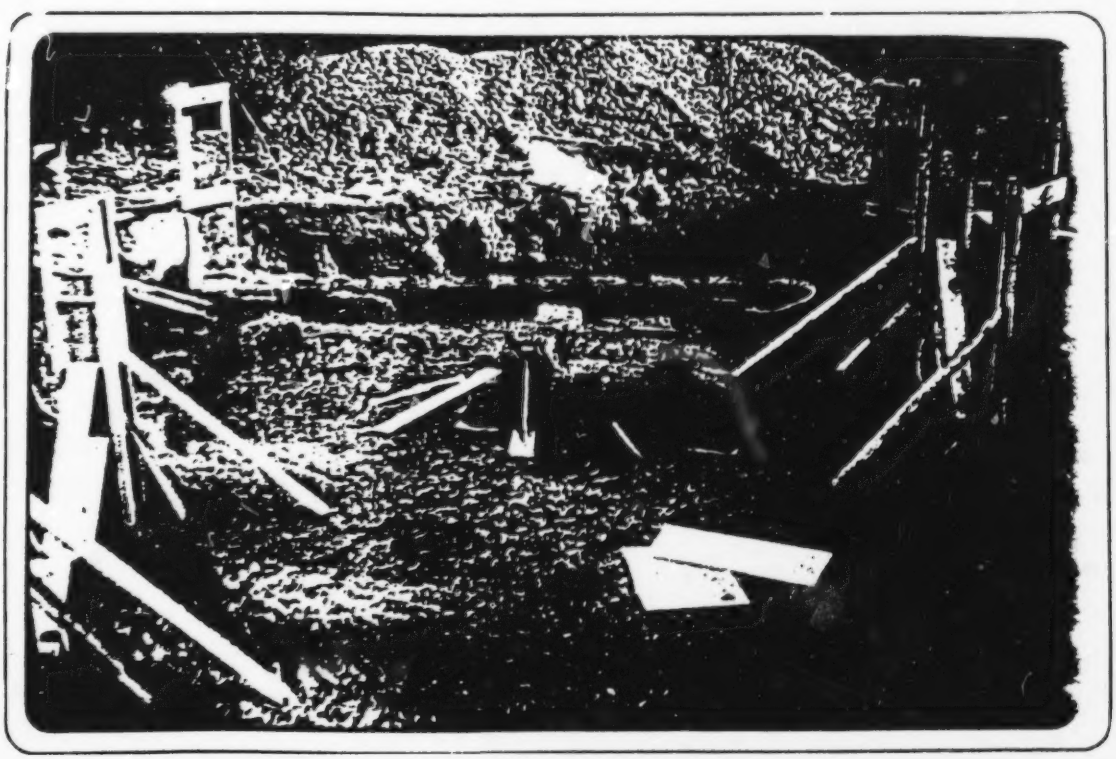
C.3

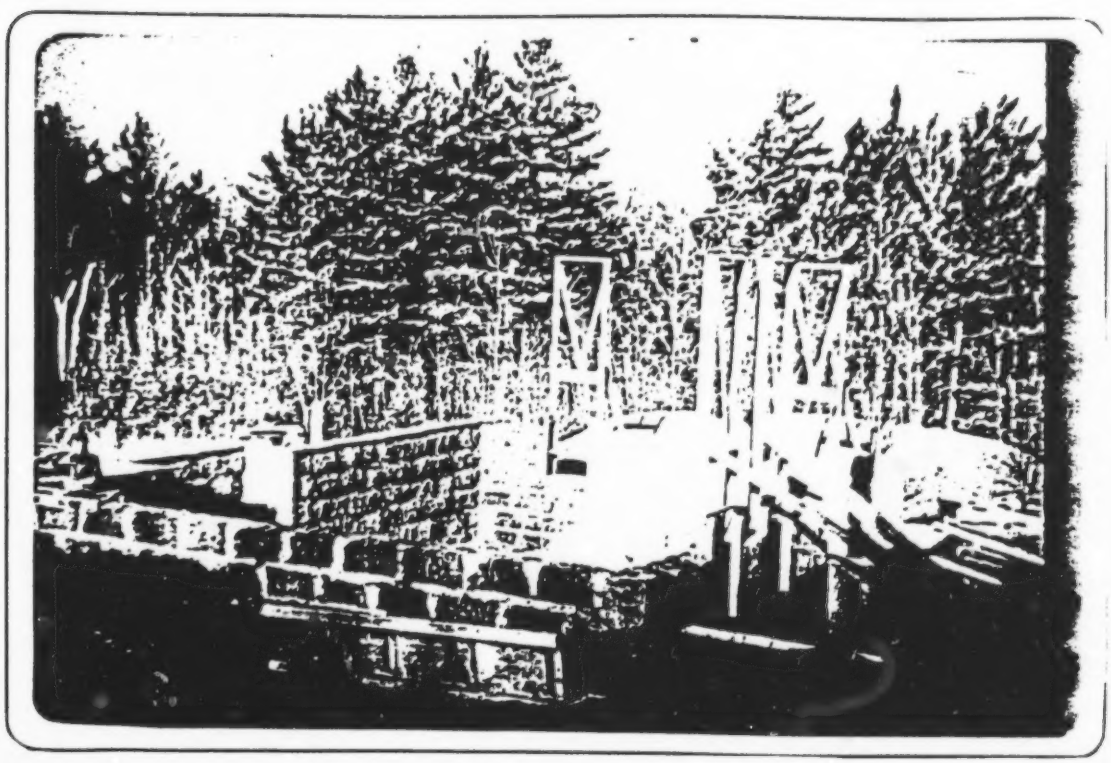


50.8mm/304.8mm rafters every 610mm.

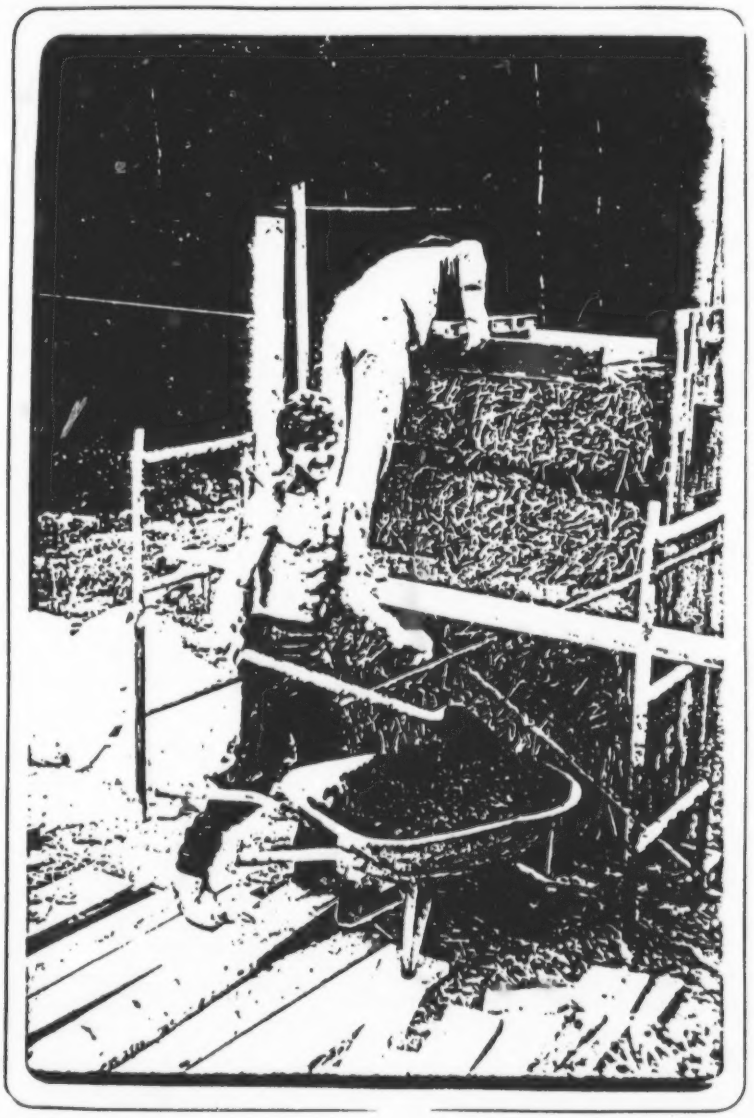
C.4.



C.5 First row of the basement walls, corner forms properly set and braced in place.

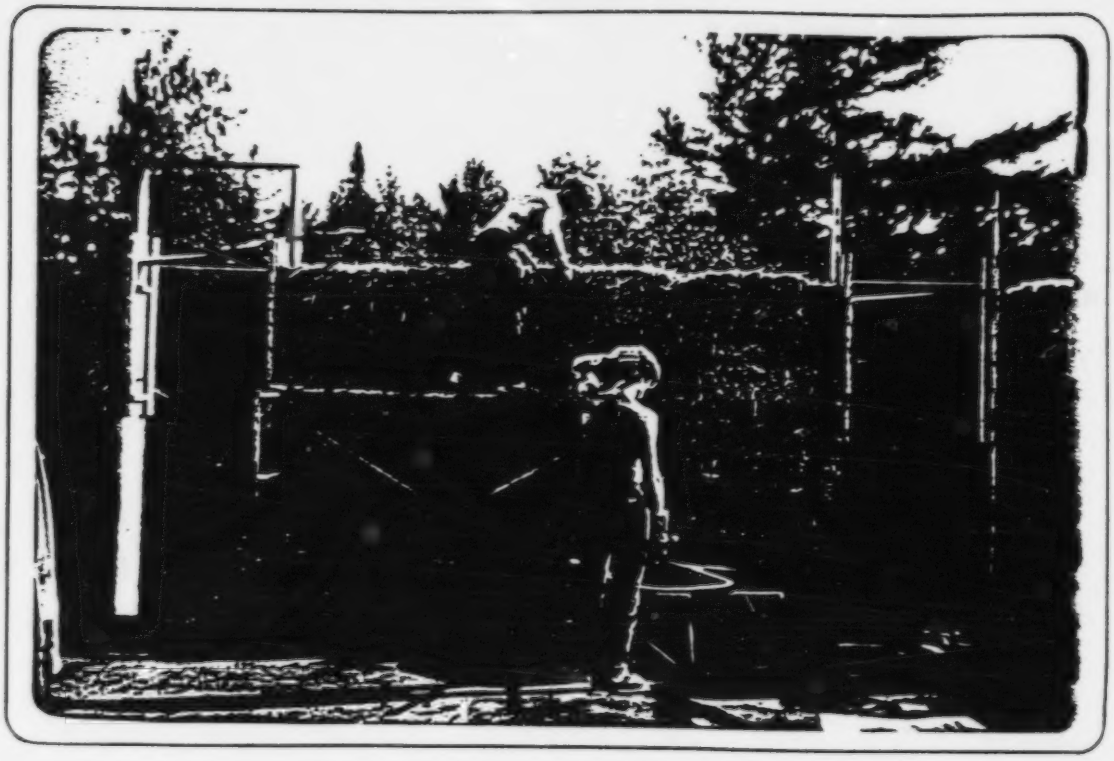


C.6 The six rows for the basement walls are completed. The window frames covering the three different levels are in place.

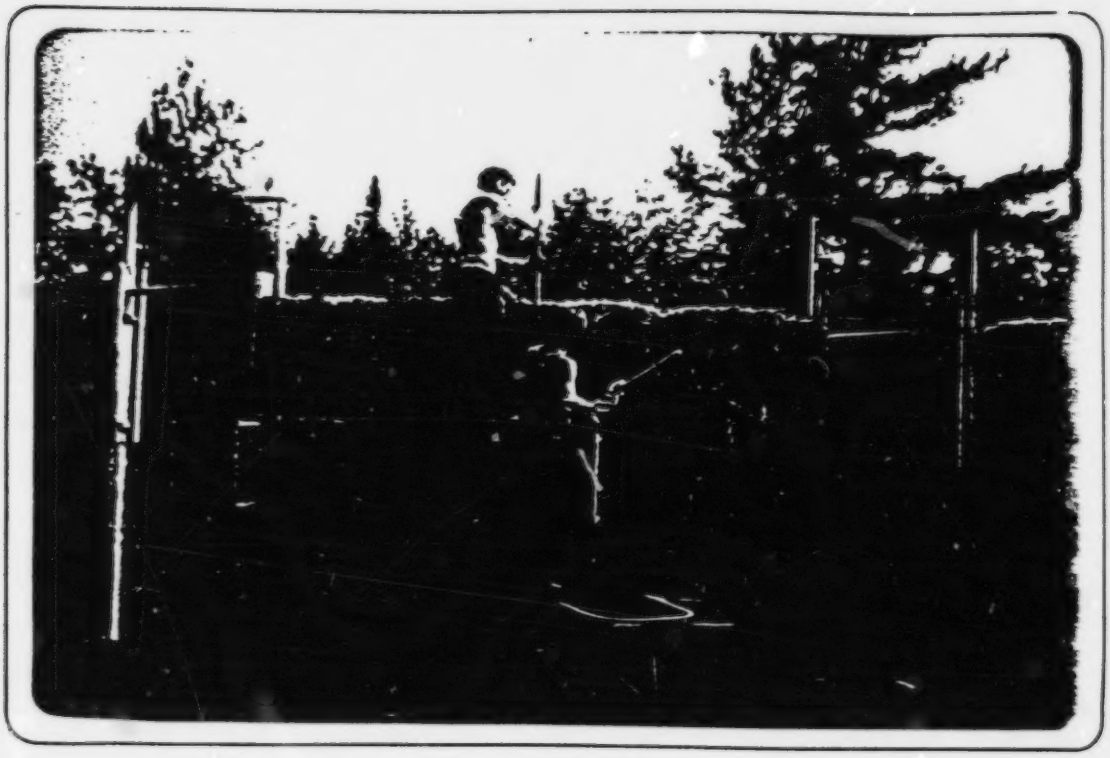


C.7 The horizontal form is set in place and leveled.

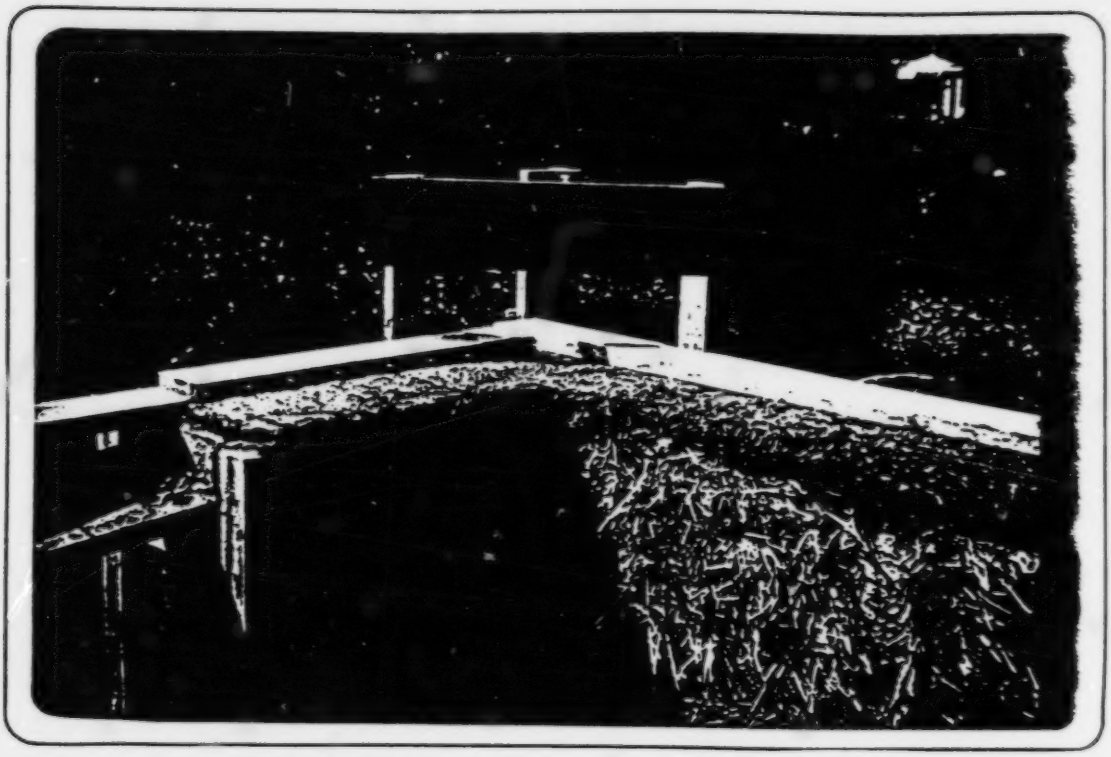
C.8 The form is filled with mortar to produce the horizontal mortar joint.



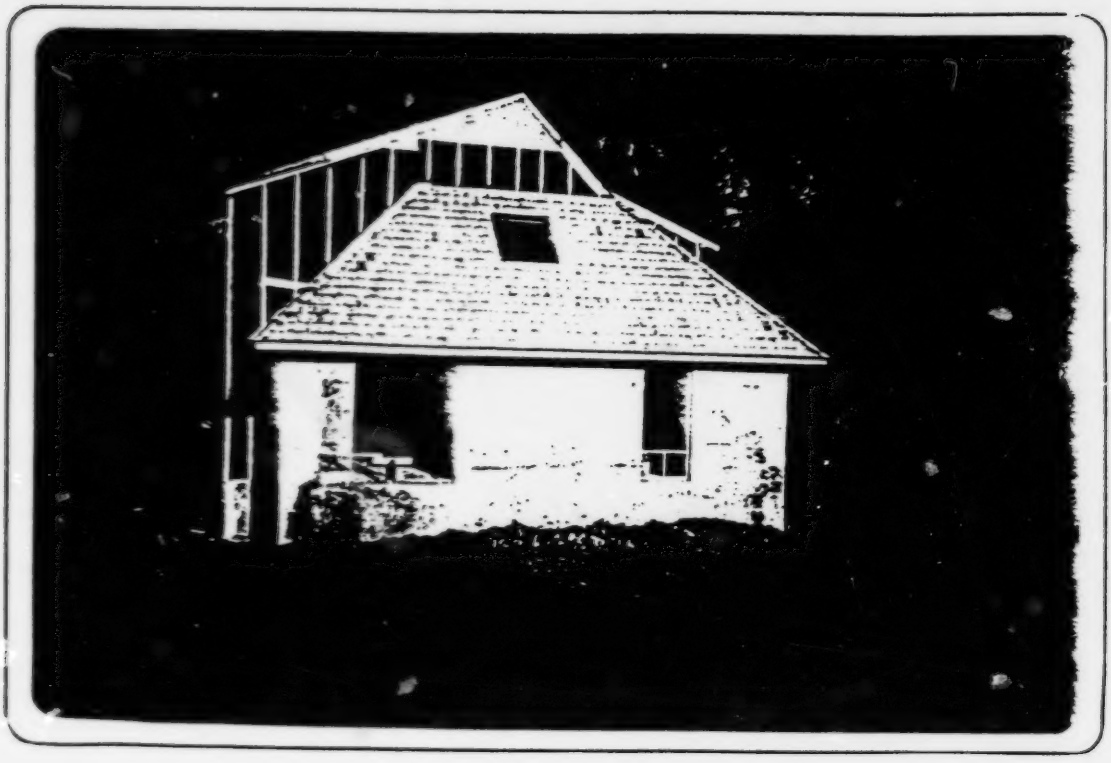
C.9 The special clamp used for the vertical form is set in place.



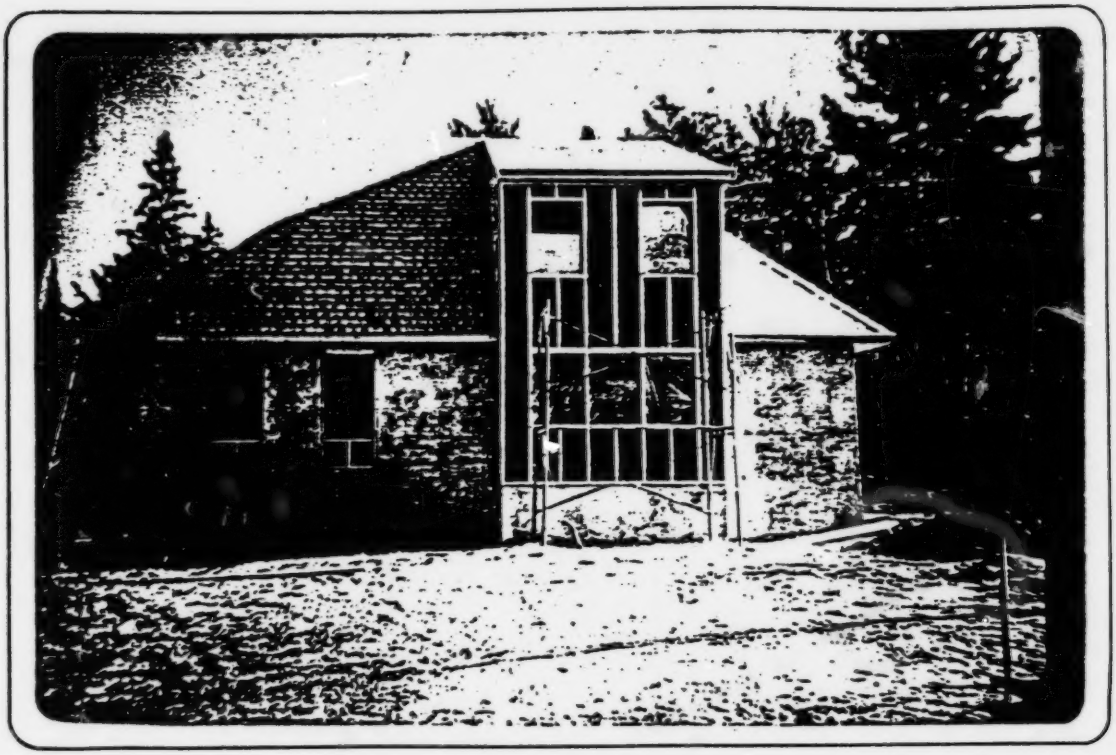
C.10 The mortar is rammed between the bales to form the vertical joint.



C.11 The walls for the main storey are completed, and the plate with nails on each side is placed on top of the last horizontal joint. Mortar will be set on each side of the plate to lock it in the structure.



C.13 Detail of the west side.



C.12 The walls received two rough coats of parging .

The joists for the floor of the second storey were fastened to the top plate of the straw and mortar walls, and the roof is built on top of them.

D. THE HOUSE IN THE LAC BERNARD (LA PÊCHE)

1. Characteristics

This house is 13,411 mm long, 6,706 mm wide, it has a full basement plus two storeys. The basement, the main floor, and the second floor have a surface of 75 m^2 (807.72 $ft.^2$). The total floor area is 225 m^2 (2,422 $ft.^2$).

On the east side where ground level is lower, half the basement wall is done with straw and mortar. This slightly curved east wall stands 7,620 mm above ground level, and 6,706 mm is made out of straw bales and mortar.

The south wall, which will be used for solar gain, has been framed since it's going to be mostly a glass surface. The north and west walls are made of straw and mortar.

2. Structure

In this house we have demonstrated the possibility to build more than two storeys with this technique. We have also used the walls strength to carry the structural wood bears supporting the floor and the roof. (Fig.).

3. Humidity

We had a problem with humidity in some of the bales on the top row because the wind blew the plastic off the walls during one rainy week.

We had an interesting experiment set up by those circumstances. Half the wall was protected by the roof and half was exposed to the rain. When we came back on the work site we noticed some wet spots on the top of the exposed wall. We then decided to punch holes on the inside of the walls to check for wetness. We found that the half protected by the roof remained completely dry, but the exposed half was wet on its top row. We then broke open the inside surface of the top row to see clearly what was happening. Since the structure is done with heavy gravel it has a certain porosity. When it's not sealed off on the top, the structure will saturate with water during rainy periods. The water will slowly soak in, following the mortar joints around the straw bales. We found that the bales had a ring of wetness around them but the inside was dry. Those bales were pulled out and replaced.

These observations can be linked with an experiement that was done on my house in Rupert (La Pêche). Three years ago, I built a wall connected to my house to test the load bearing strength. I left it standing completely exposed for two years. The north part of the wall that served for the load bearing test was plastered, but the east part was not. For two years I witnessed the east wall getting

wet and drying off without dampening the straw. But when I broke open the north wall the straw was entirely wet. The capacity of the wall to eliminate wetness when it's plastered is considerably reduced. Therefore it's recommended to put the roof on the house before plastering the walls.

On a framed house the same situation would be applicable. To build and finish the wall with insulation and gypsum boards on the inside without protection of the roof would be looking for trouble.

It's possible to prevent the walls from getting wet even if the surfaces are plasted, by making sure the plastic stays on top or by waterproofing the top surface with a coat of light tar.

4. Materials cost and labour involved

a) Cost breakdown for material

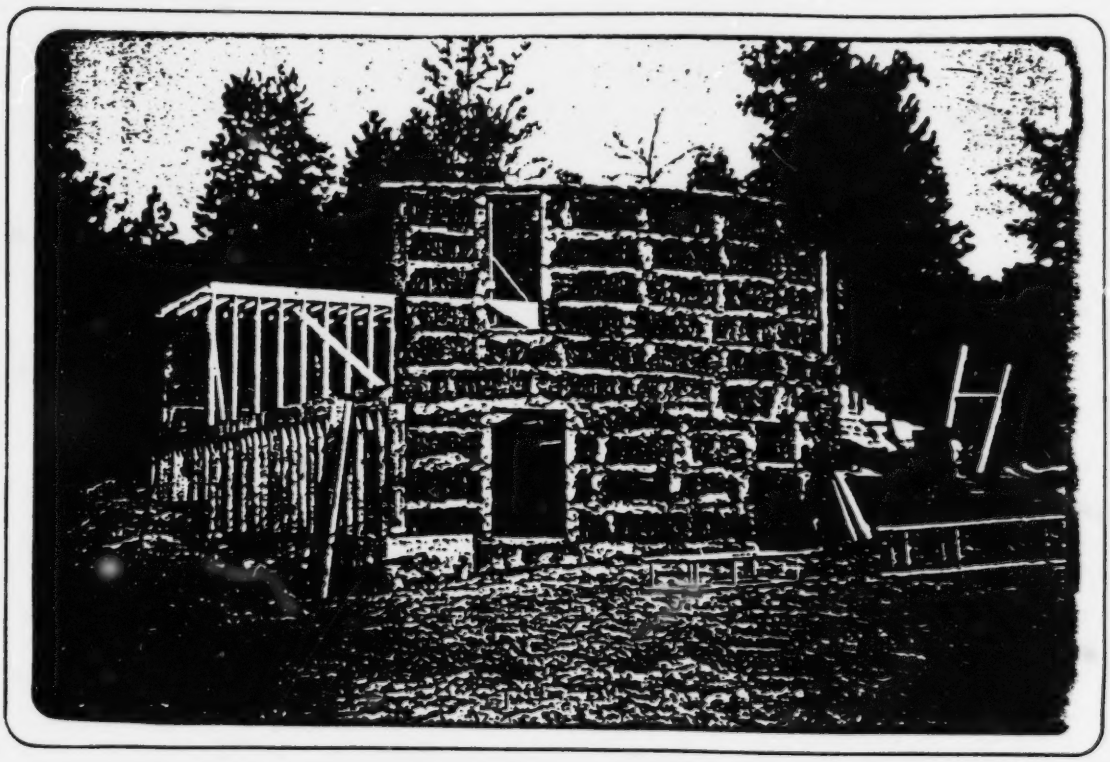
Item	Amount	Unit Cost	Total Cost
Straw bales	367	$ 1.50	$ 550.50
Cement bags	130	$ 5.50	$ 747.50
Lime bags	90	$ 5.95	$ 535.50
White Cement bags	3	$ 19.34	$ 58.02
	Sub-Total		$1,891.52
	Prov. sales tax		$ 170.24
	Total		$2,061.76
Gravel loads	4	$ 30.00	$ 120.00
Sand loads	3	$ 45.00	$ 135.00
	Total materials cost		$2,316.76

b) Labour involved

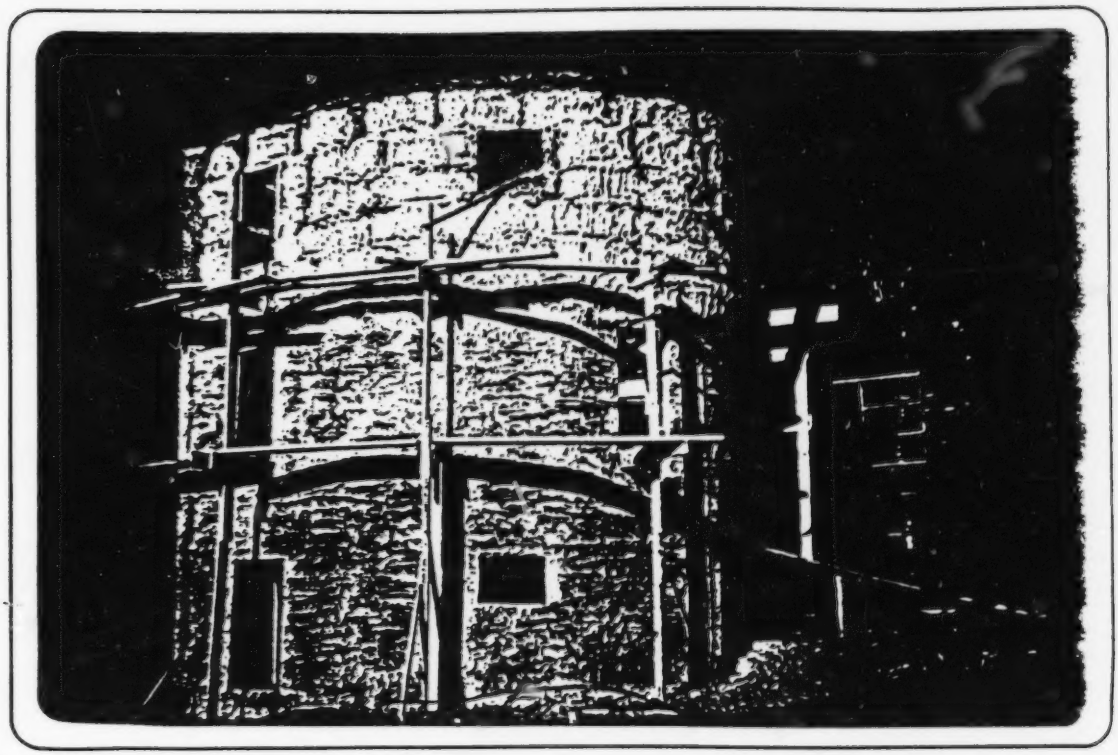
It took approximately ten days to do the structure and ten days to apply the mortar coats and the whitewash paint with our three men crew. We were slower than at Chelsea because we were learning to work as a team, and we had a number of problems to solve that were not encountered before. As an example, we had to build more than a storey above ground level and we had to find a solution to get the mortar quickly on to second level. For that purpose we had to build ramps and use a rope to pull up the wheelbarrow. Special scaffolds had to be built for the high curved wall.

At this house we solve a number of problems, and we applied the acquired experience on the main storey we built later in Chelsea.

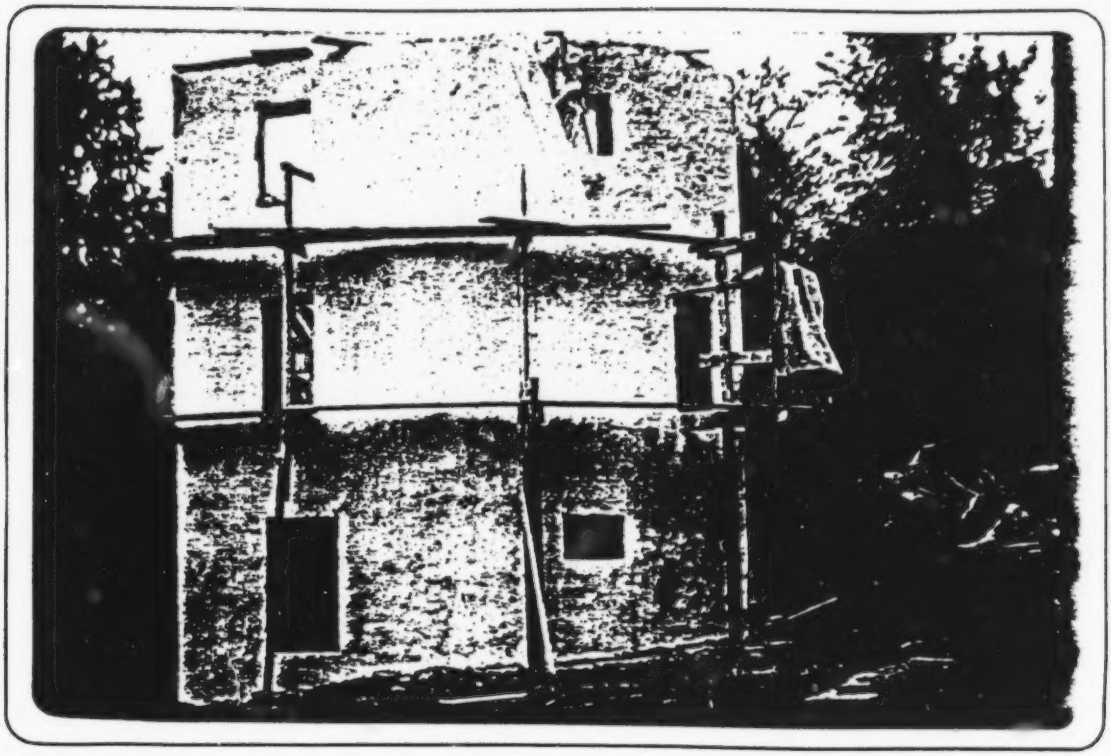
5. Floor Plans and Wall Details



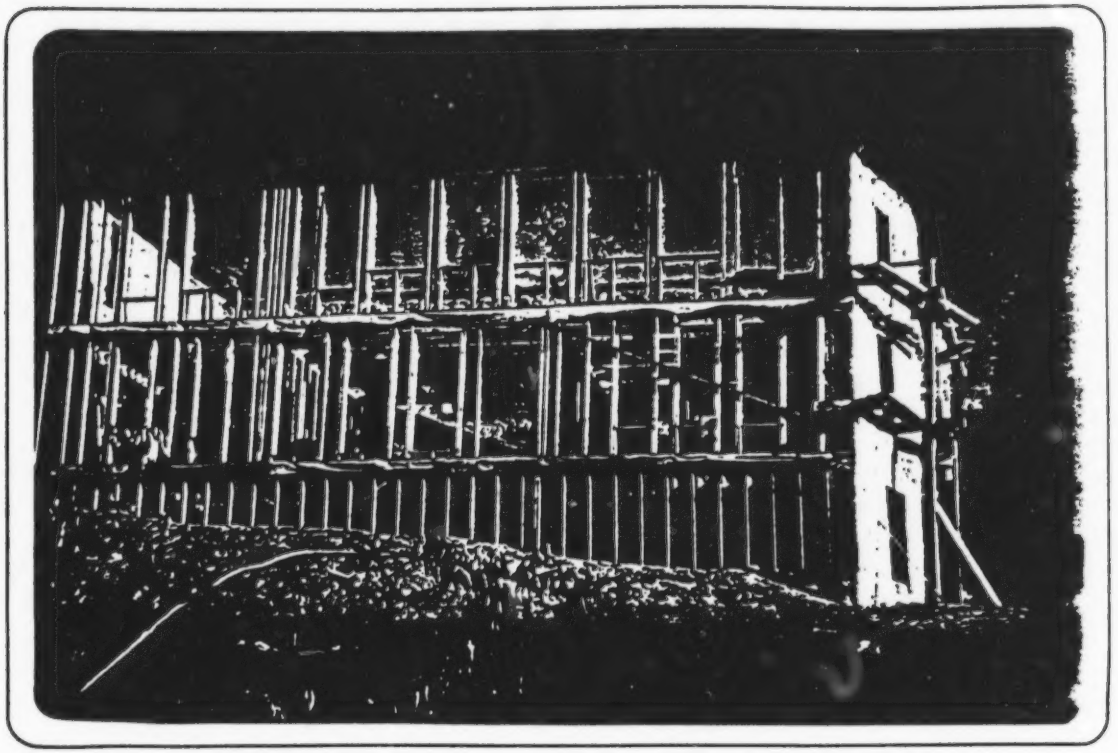
D.1 The east curved wall, with the first storey and half the basement wall done with straw and mortar.



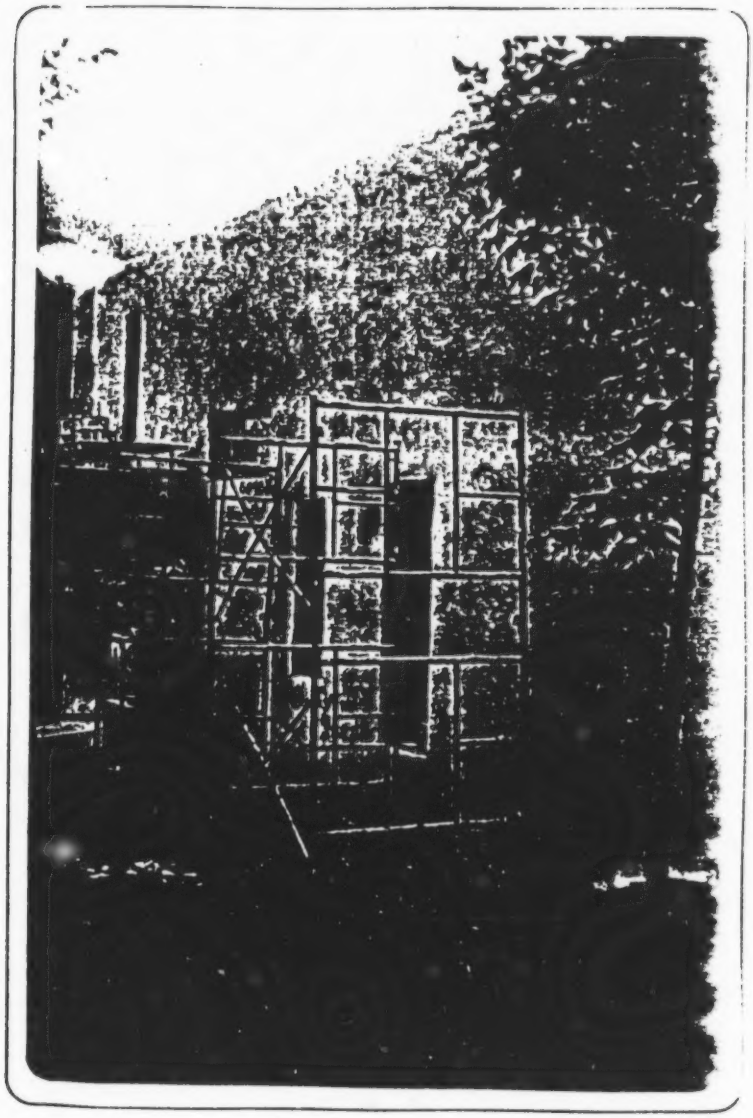
D.2 The same east wall with its two and a half storeys made out of straw and mortar.
The first rough coat of parging was applied.



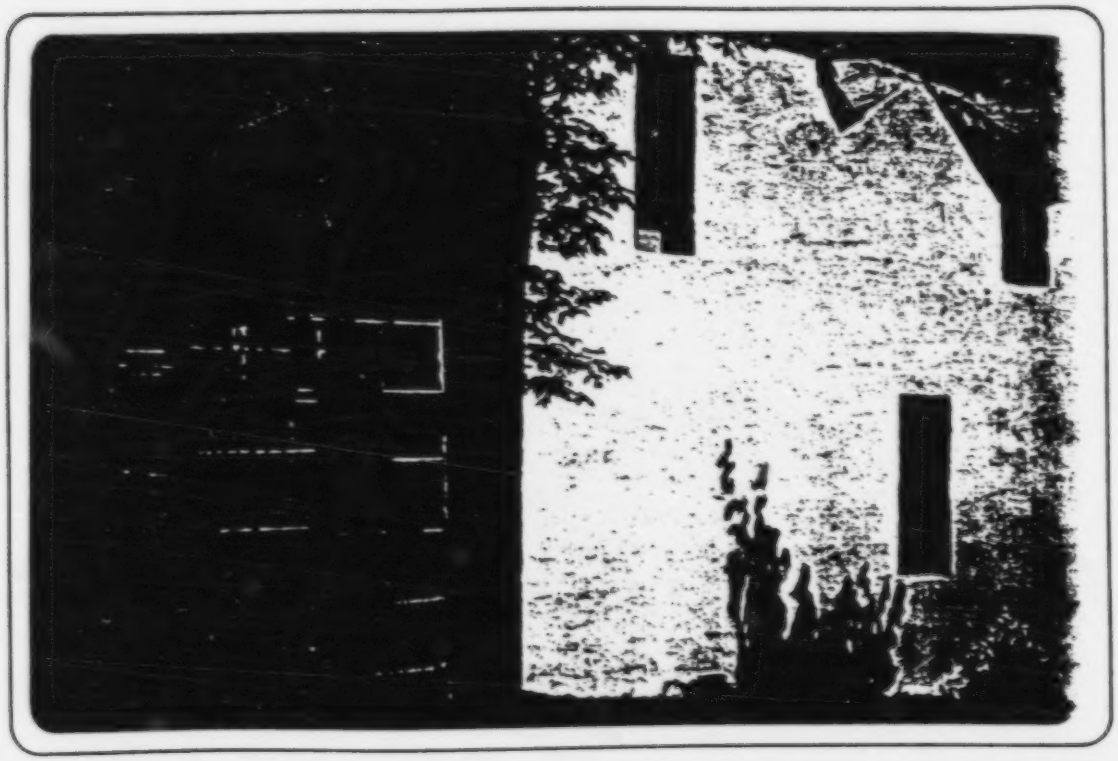
D.3 The surface received the second coat of parging and the whitewash finish.



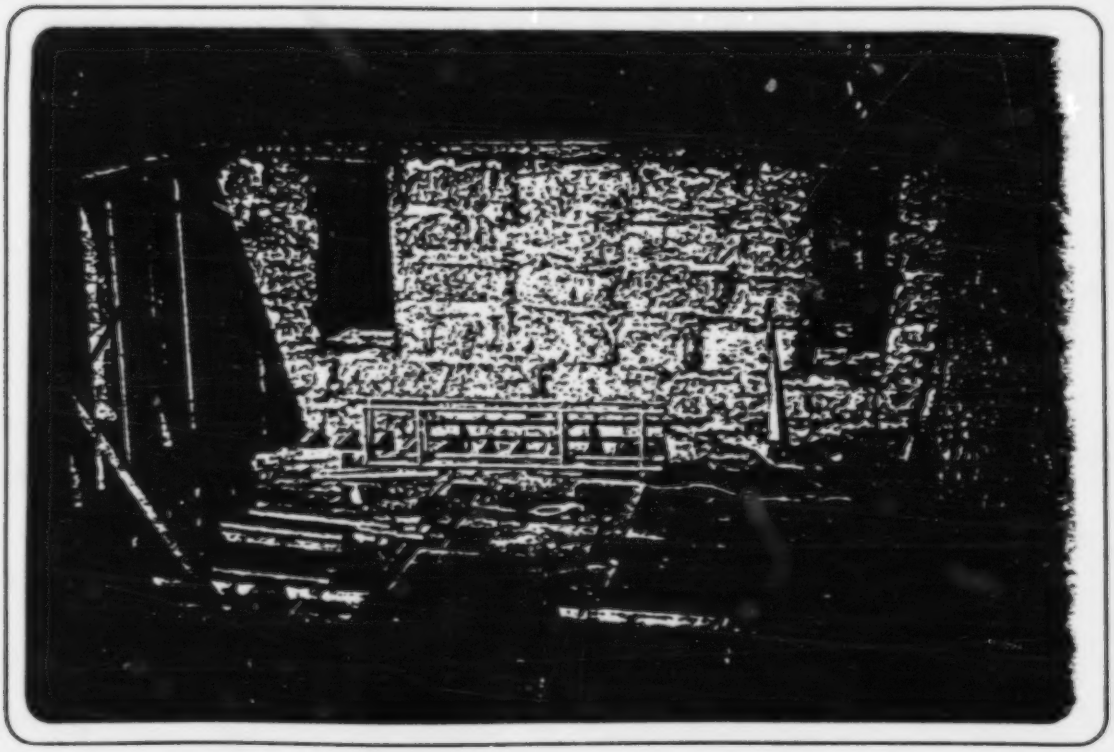
D.4 The south framed wall, which will be mostly a glass surface for solar gain.



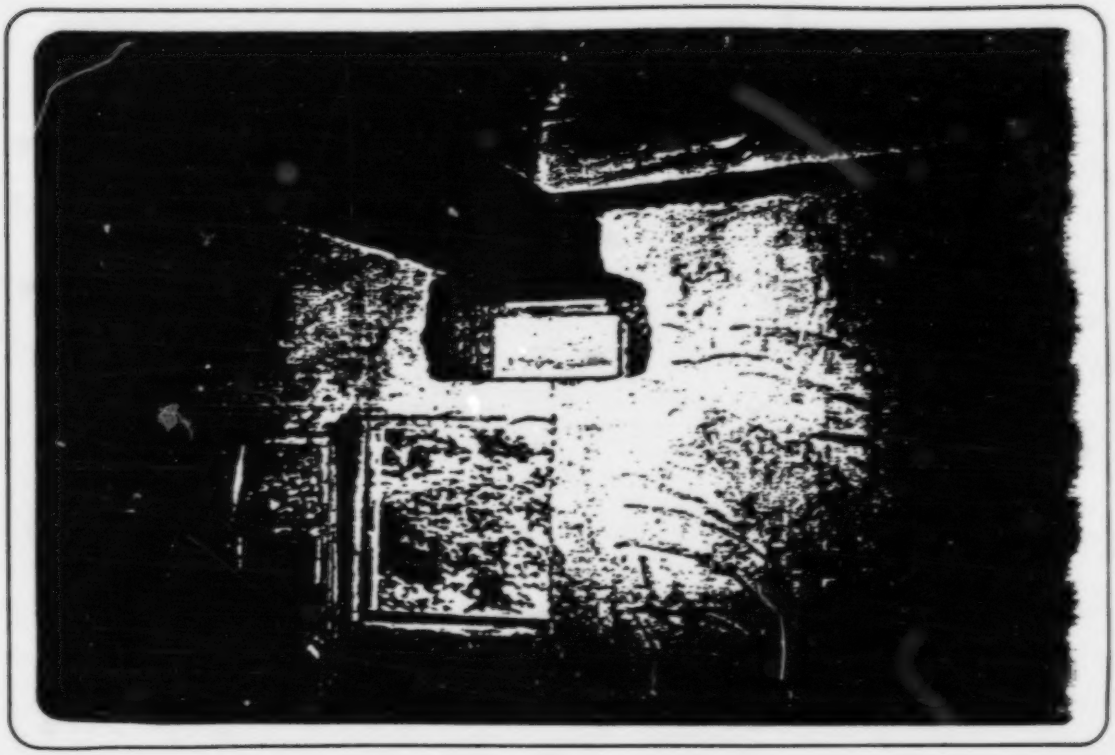
D.5 The north wall with few openings for maximum energy efficiency.



D.6 The west wall also built for maximum energy efficiency.



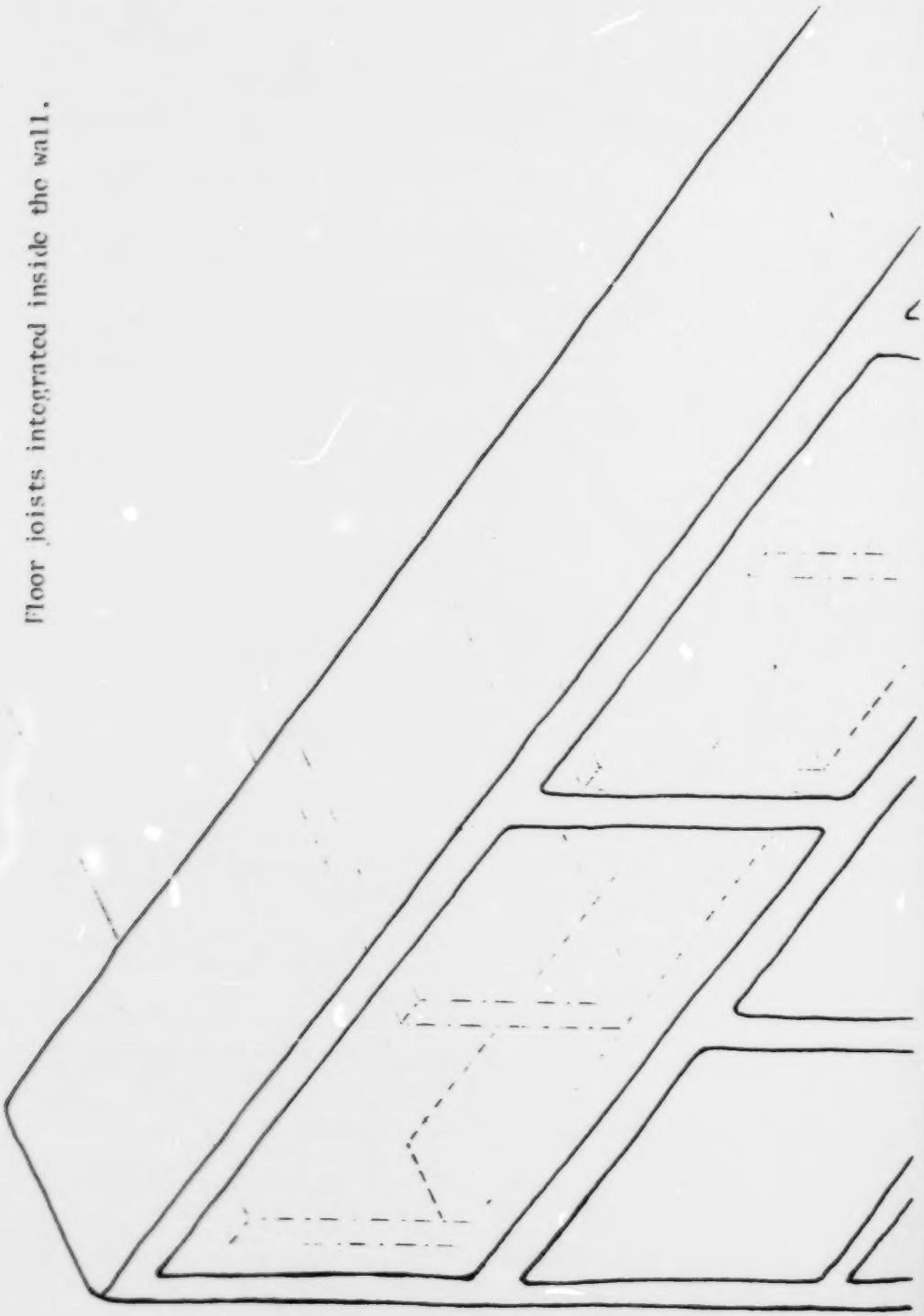
D.7 Inside walls with the first coat of parging.



D.8 Structural wooden beam supporting the rafters for the flat roof. The beam is supported by the structure of the straw and mortar wall.

The beams supporting the floor for the second storey also take their support from the structure of the straw and mortar walls.

Floor joists integrated inside the wall.



D.9

E. CONCLUSIONS

1. Practical example

The two different house construction projects give accurate information on material cost and labour involvement.

From the Lac Bernard house it's possible to establish a price per surface unit for materials: to do the 130.8 m^2 (1,408 $ft.^2$) wall it cost $2,136,76; that is $17.71 per square metre of wall surface ($1.65/$ft.^2$).

At the Chelsea house it took four days to build the structure for the main storey. We laid down 192 straw bales for the walls. The average was about 50 bales per day. A three men crew would do the two mortar coatings on the inside and outside surfaces for the walls, plus a coat of whitewash in six days.

The following example will give a better perspective of the effectiveness of this techniue: to build a 120.77 m^2 (1,300 $ft.^2$) house it would take a three men crew, six days to build the structure, and eight days to finish the inside and the outside surfaces of the walls with two coats of mortar, and a coat of whitewash paint.

The total cost of materials including all finish coatings, would amount to $2,200.

2. Technical achievements and future developments

a) Forms

At the Chelsea house, corner forms were improved but the major contribution was the introduction of forms for vertical and horizontal mortar joints.

The vertical form was made of two plywood panels 350 mm square with two rows of nails on the sides to keep the panels on the bales before the clamp was set in place. Even if we gained speed, the operation was too laborious. The year after at the Lac Bernard house, I developped a clamp with steel plate 300 mm by 350 mm which could be set in place in one operation. This tool proved to be tremendously efficient and the time it takes to do a vertical mortar joint was reduced by half.

The horizontal form we used at the Chelsea house was 1,500 mm long and 500 mm wide. This form was made of 20 mm by 125 mm planks. The four corners had metal tracks with a sliding wing nut designed to adjust the thickness of the mortar joint. This form also increased our speed but the fact we had to set the level on the four corners of the form made it also too laborious.

The year after, at the Lac Bernard house, I introduced a form of the same dimension, except for the cross sides corresponding to the wall's width were reduced to 60 mm instead of 125 mm large. This measurement represents the minimum thickness of the joint. Levels were placed on the form, which enables us to set it in one operation.

I mentioned that our speed was tremendously increased with the vertical form, but here, the change was spectacular: we acquired great accuracy (since only half an inch on the level in going around with the mortarjoint) and the slowest operation became the fastest one.

b) Modified bales

The most important factor besides the tools are the straw bales themselves. Combined with the forms they are the mould for the mortar structure. On the regularity of their shape depends the amount of concrete for the structure and the amount of plaster for the surfaces.

All kinds of crooked and soft bales were used on the houses I built, and they slow down work considerably.

Two years ago, I explained to CMHC that it would be possible to modify a baler. This work was done last spring. The purpose was to reduce the width of the bale and to get each side neatly cut.

To do so, the plunger compacting the straw was reduced from 500 mm to 350 mm in width. Walls made of steel plates were added to the chamber so it would correspond to the modified plunger. Another set of knives were added on the plunger and the chamber. A small opening was punctured on the wall receiving the injected straw, in order to eliminate the cut ends of the straw.

In field tests the modified baler proved to be extremely effective. The bales produced were neatly cut, straight, and with true flat ends, to an unprecedented degree achieved with straw. A local farmer who assisted in the field trail was astonished by the quality and regularity of the bales, which resembled construction blocks.

These fine-cut narrower bales will provide increased uniformity in the strucutre, enabling straight walls free of bumps and hollows. These bales provide good parging surfaces both on the inside and on the outside, since the folded side of the bale has been eliminated. Previously, in the case of the standard bales, the side of the bale with the folded straw surface has proven to be a poor parging surface due to the looseness of the straw.

The modified baler was developed as the construction of the houses was completed. It was therefore not possible to use the narrower bales in construction. However, based on the straw bale and mortar

construction experience to date, the utilization of the narrow straight-cut bale may potentially reduce construction cost by half, primarily due to savings in labour.

c) Sprayed concrete parging

The next step to improve the technique will be the introduction of concrete pumps to coat the walls. The parging will be done in one operation with the same three-men crew, one mixing the mortar, one shooting the walls, and one smoothing the surface with a large trowel.

d) Final comment

The basics of this technique can be learned in a few days. A two week practical training is sufficient to teach all intricacies related to this construction method. These factors make it a well suited self-help building method for people with limited resources. It is also applicable to high profile housing, because its moulded concrete structure lends itself to the imagination of the builder, which can be shaped into straight lines, curves, or arches.

The building materials are perfectly safe for people's health, are abundant and readily available. The method offers a low cost house with high standards, which would contribute greatly to solve housing problems in the future.

In the light of what is exposed in this report, a serious consideration should be granted to the straw bale/mortar building method.